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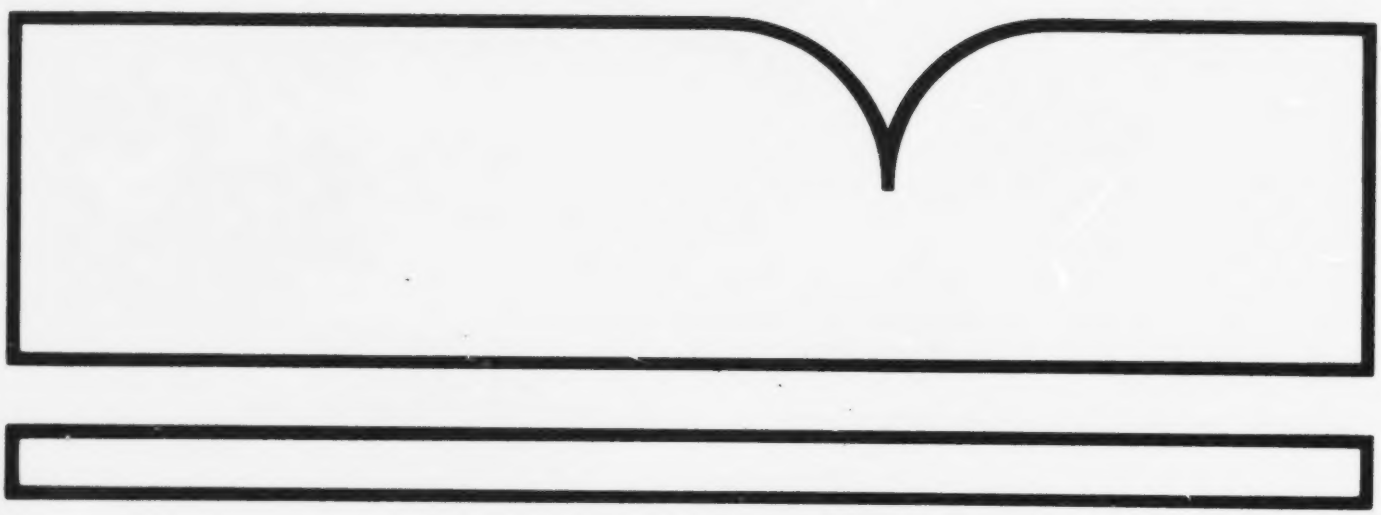

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MINIMIZATION OF COMBUSTION BY-PRODUCTS: CHARACTERISTICS OF HAZARDOUS WASTE

by

C. C. Lee and George L. Huffman

Paper to be presented at the
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It has been well recognized that, although there are many potential solid waste treatment technologies, none are as universally applicable as incineration for the treatment of the many types of waste which are governed by the many different Federal laws and State regulations. However, incinerators may release trace amounts of unwanted combustion by-products, particularly if the incinerators are not well designed or properly operated. Control of emissions of combustion by-products (CBPs) is one of the major technical and sociological issues surrounding the implementation of incineration as a waste treatment alternative. Much of this is due to the lack of detailed knowledge about CBPs. The Clean Air Act Amendment is emphasizing the control of toxic air pollutants from all combustion sources; some of these pollutants are CBPs. CBPs include: (1) unburned principal organic hazardous constituents (POHCs); (2) products of incomplete combustion (PICs); (3) metals emissions; and (4) residuals/ashes. This Paper is a part of a series of writings on the subject of the CBP issue from EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio. It specifically addresses the aspect of hazardous waste characteristics. The main objective of the series is to compare combustion by-products from all combustion sources including fossil fuel combustion and waste incineration, which hopefully will serve as an initial step in the eventual minimization of the release of CBPs to the environment.

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ABSTRACT

It has been well recognized that, although there are many potential solid waste treatment technologies, none are as universally applicable as incineration for the treatment of the many types of waste which are governed by the many different Federal laws and State regulations. However, incinerators may release trace amounts of unwanted combustion by-products, particularly if the incinerators are not well designed or properly operated.

Control of emissions of combustion by-products (CBPs) is one of the major technical and sociological issues surrounding the implementation of incineration as a waste treatment alternative. Much of this is due to the lack of detailed knowledge about CBPs. The Clean Air Act Amendment is emphasizing the control of toxic air pollutants from all combustion sources; some of these pollutants are CBPs. CBPs include: (1) unburned principal organic hazardous constituents (POHCs); (2) products of incomplete combustion (PICs); (3) metals emissions; and (4) residuals/ashes.

This Paper is a part of a series of writings on the subject of the CBP issue from EPA's Risk Reduction Engineering Laboratory in Cincinnati, Ohio. It specifically addresses the aspect of hazardous waste characteristics. The main objective of the series is to compare combustion by-products from all combustion

sources including fossil fuel combustion and waste incineration, which hopefully will serve as an initial step in the eventual minimization of the release of CBPs to the environment.

INTRODUCTION

Decisions about how to manage the wastes of today and tomorrow are becoming increasingly more difficult. The main reasons for the difficulty include:

- Increasing amounts of waste as time goes on, because of the increase of population and industrial output;
- Declining landfill capacity;
- Concerns about the risks associated with toxic combustion by-products (CBPs) if the wastes are incinerated [in brief, CBPs are the unwanted combustion residues remaining in combustion ash and in combustion gases (metals emissions, PICs, the products of incomplete combustion, and unburned POHCs, the unburned principal organic hazardous constituents)];
- The concept of "NIMBY" (not in my back yard) which leads the public to oppose almost any type of waste management facility; and
- Rising disposal costs.

In addition to the above factors, different types of waste are governed by different environmental laws and regulations. For example, hazardous waste is governed by the Resource Conservation and Recovery Act, toxic substances by the Toxic Substances Control Act, and municipal sewage sludge by the Clean Water Act.

In comparing all potential waste treatment technologies, both EPA and industry have often found that incineration is the best available technology for

disposing of the many different waste streams (1). However, waste incineration may emit trace amounts of unwanted CBPs. Risk assessments have shown that, of the CBPs that exit in stack gases, the risks to human health from metals emissions ranged up to 2 to 6 orders of magnitude higher than the risk values for POHCs and PICS (metals risks were estimated at 10^{-8} to 10^{-5}) (1). Of the three classes of CBPs in stack gases (metals, POHCs and PICs), metals are probably the easiest to control from a technology advancement standpoint.

Hazardous waste is a sub-set of solid waste whose statutory definition is defined in Section 1004 of the Solid Waste Disposal Act (SWDA) of 1965 [also known as the Resource Conservation and Recovery Act (RCRA), because SWDA was amended by RCRA in 1976] as follows:

> Any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agriculture operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954, as amended (in RCRA, Section 1004) (2).

RCRA divides solid waste into three major categories; namely: (1) hazardous waste under Subtitle C; (2) municipal waste under Subtitle D; and (3) medical waste

under Subtitle J. This Paper will discuss the specific characteristics of hazardous waste (also referred to as "RCRA waste" herein) and how to minimize the impact of CBPs on the environment.

HAZARDOUS WASTE: DEFINITION, CHARACTER AND AMOUNTS

Definition of Hazardous Waste

Hazardous waste is a sub-set of solid waste. Its statutory definition is defined in RCRA Section 1004 as follows: hazardous waste means solid waste, or combinations of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics, may:

(1) Cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

(2) Pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed (2).

Using the above definition, EPA established four "listing" categories and four "characteristic" categories of hazardous wastes in 40 CFR Part 261. These categories and their waste identification (ID) codes are shown in Table 1 (2).

TABLE 1. WASTE TYPE AND WASTE CODE

Waste Type	Hazardous Code	Waste ID Code
Listed hazardous waste		
1. Waste from nonspecific sources		F001 - F028
2. Waste from specific sources		K001 - K069
3. Toxic waste	T	U001 - U249
4. Acute hazardous waste	H	P001 - P122
Characteristic hazardous waste		
1. Ignitable waste	I	D001
2. Corrosive waste	C	D002
3. Reactive waste	R	D003
4. Extraction Procedure (EP) toxicity waste	E	D004 - D017

Therefore, a waste is a hazardous waste, if it satisfies one of the following criteria:

- Is listed as a hazardous waste in RCRA regulations;
- Meets one or more of the following characteristics: ignitability, corrosivity, reactivity or toxicity;
- Is not excluded from the hazardous waste definition.

Characteristics of Hazardous Waste

Hazardous waste is a very broad category of materials, much of which is generated by industry. Its physical form can be solid, liquid, gas, or mixture, and its chemical properties can be best described by its:

(1) Ignitability: The waste which is capable during routine handling of causing a fire or exacerbating a fire once started.

(2) Corrosivity: The waste which is: (1) aqueous and has a pH of less than or equal to 2.0 or greater than or equal to 12.5; or (2) a liquid and corrodes steel at a rate greater than 6.35 millimeters (0.250 inches) per year under specified testing procedures.

(3) Reactivity: The waste which is extremely unstable and has a tendency to react violently or explode during stages of its management.

(4) Extraction Procedure (EP) Toxicity: A test that is designed to identify wastes likely to leach hazardous concentrations of particular toxic constituents into the ground water as a result of improper management (2).

Appendix VIII of 40 CFR Part 261, which provides specific constituents of concern within hazardous waste, lists approximately 320 identifiable organic compounds. Including all possible waste entries such as inorganics, organometallics, PCDDs (dioxins), PCDFs (furans) and N.O.S. (not otherwise specified) compounds, it contains approximately 850 compounds. Appendix VIII, which was first published in the May 19, 1980 Federal Register, has been updated by EPA semi-annually since then.

Amount Produced

In 1984, EPA conducted a study to estimate the quantity of RCRA-regulated hazardous wastes generated in 1981. The study concluded that in 1981 approximately 264 million metric tons of hazardous wastes were generated in the United States from the following major industries (3):

- Chemical & Petroleum: 71%
- Metal-Related Industries: 22%
- Other Industries: 7%

In 1989, EPA released a "Fact Sheet" report (4). The report estimated that there are currently about 525 million tons of RCRA hazardous waste managed in the United States each year. The majority of this waste is wastewater and the remaining non-wastewaters are mainly sludges and solid residuals. Three regulatory initiatives and activities are expected to increase the current estimate of hazardous waste generated in the U.S.; these are (4):

(1) Toxicity Characteristic (TC) Rule: The rule which was finalized in March 1989 regulates additional hazardous wastes. Most of these are wastewaters that can no longer be land disposed after the TC rule was promulgated;

(2) Bevill Amendment to RCRA: In the past, large volumes of mineral processing wastes were temporarily exempt from hazardous waste regulations. As a result of this Amendment, the exemption for many of these wastes was removed. At least several million tons of mineral processing wastes per year will be regulated as hazardous waste; and

(3) EPA's Updating Studies: EPA routinely investigates non-hazardous wastes to determine whether they should be listed as hazardous wastes. Over

the next few years, EPA estimates that another 2 million tons of newly listed waste will need to be managed each year in the hazardous waste system.

Amount Incinerated

The earlier study (3) indicated that only a fraction (0.6%) of hazardous waste (1.7 million tons) was incinerated in 1981. However, more hazardous waste has been incinerated since the enactment of the land disposal restriction (LDR) policy required by the Hazardous and Solid Waste Act (HSWA) of 1984. The LDR policy prohibits the land disposal of certain hazardous wastes unless the wastes are treated or unless it can be demonstrated that there will be "no migration as long as the wastes remain hazardous." Also prohibited from land disposal are bulk or non-containerized liquid hazardous wastes, certain dioxin-containing hazardous wastes, and some solvent wastes. Because of this policy, more incineration has been used to destroy the RCRA wastes. The LDR policy divided hazardous wastes into three broad categories and prohibited land disposal of these wastes beyond the dates specified in Table 2 (40 CFR 268.10 - 268.12) (4).

Under the studies being done to determine the Best Demonstrated Available Technology (BDAT), the treatment standards being set by EPA require that a wide variety of waste treatment methods be investigated for restricted wastes. Incineration is usually required for wastewaters and non-wastewaters that contain high levels of synthetic organic chemicals. Wastewaters containing low concentrations of organics can be treated through biological activity in a manner similar to domestic sewage treatment. For wastes that contain metals and

TABLE 2. RCRA WASTE AND LDR SCHEDULE	
Waste Category	LDR Schedule (Congress required that EPA's treatment standards be available before the deadline of each waste category)
The first category: solvent and dioxin-containing wastes	11/8/86
The second category: 12 classes of hazardous wastes originally listed by the State of California	7/8/87
The third category, which has been referred to as "schedule wastes," includes all other wastes	8/8/88: At least 1/3 of all listed RCRA waste (The "First Third") 6/8/89: At least 2/3 of all listed RCRA waste (The "Second Third") 5/9/90: All remaining listed RCRA waste and all RCRA characteristic waste (The "Third Third")

inorganic pollutants that cannot be destroyed by incineration, BDATs are generally chemical precipitation for wastewaters, and chemical stabilization and solidification for non-wastewaters (4). The Fact Sheet also suggested that (4):

- About 46.5% of RCRA wastes (245 million tons) could be eligible to be incinerated under the provisions of the RCRA incineration standards;
- About 46.5% (245 million tons) are managed in wastewater tanks whose effluents are discharged to publicly owned wastewater treatment plants or to streams in compliance with Clean Water Act Regulations; and
- About 7% of RCRA wastes (35 million tons) were placed in or on the land. These are the wastes affected by the LDR policy. Most of these wastes (about 30 million tons) were pumped deep into the ground (underground injection wells) regulated under the Safe Drinking Water Act. About 5 million tons are disposed on or just below the land surface in RCRA-regulated landfills, surface impoundments, waste piles, and land application units. As a result of LDR policy, all of these wastes have to be treated before they are land disposed.

Background information about the hazardous waste to be burned is generally available. Factors to be considered in evaluating hazardous waste for incineration are:

- Dioxin/furan and PCB content;
- Moisture content;
- Potential pollutants expected in incinerator effluents;
- Inert (ash) content;
- Heating value and auxiliary fuel requirements;

- Potential health and environmental effects of the effluents;
- Physical form;
- Corrosiveness; and
- Known carcinogenic content.

A conceptual strategy for determining the wastes which are candidates for incineration is shown schematically in Figure 1 (5). In general, the waste burned must be maintained at adequate incineration temperatures or a supplemental fuel must be burned. Table 3 shows some typical waste streams that are candidates for incineration (6).

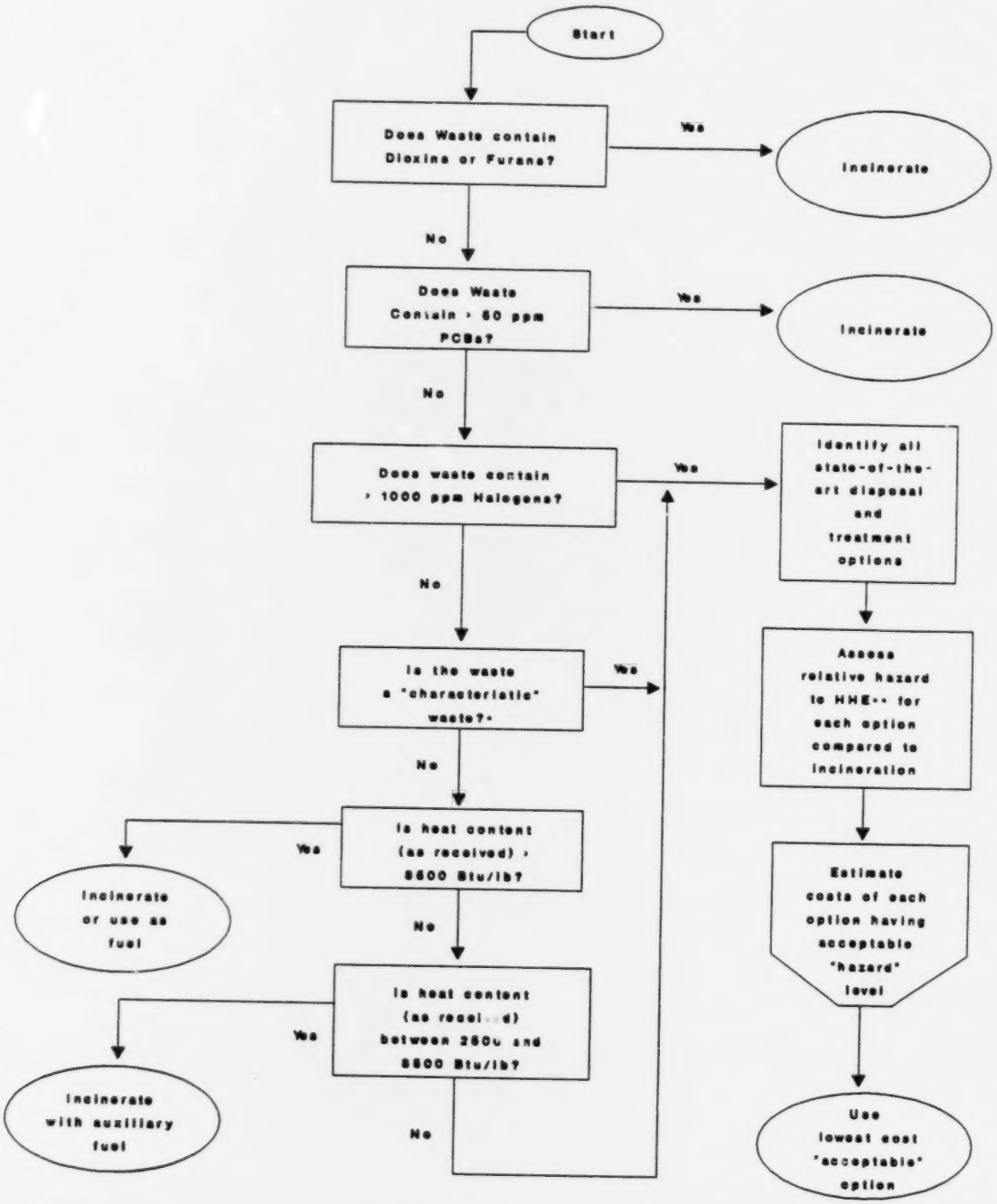
WASTE CHARACTERISTICS WHICH INFLUENCE EMISSIONS

CBP emissions are directly related to the performance of an incinerator. Some waste characteristics which have an impact on the performance of an incinerator include: (1) heating value; (2) chlorine content; (3) ultimate analysis; and (4) moisture content.

Heating Value

The heating value of a waste is a measure of the energy released when a waste is incinerated. It is measured in units of Btu/lb (1 Btu/lb = 2.324 J/g). In general, a heating value of about 5,000 Btu/lb (11,620 J/g) or greater is needed to sustain combustion. Wastes with lower heating values can be burned, but they will not maintain adequate temperature without the addition of auxiliary fuel. The heating value of the waste is needed to calculate total heat input to the incinerator where:

Heat Input (Btu/hr) = Feed Rate (lb/hr) x Heating Value (Btu/lb)



*Characteristic waste means ignitable, corrosive, reactive or EP (extraction procedure) toxicity waste.

**HHE - Health and Human Environment.

FIGURE 1. CONCEPTUAL STRATEGY FOR DETERMINING WASTE BURNABILITY

TABLE 3. GROUPS OF EPA HAZARDOUS WASTE STREAMS THAT ARE THERMAL TREATMENT CANDIDATES

Group Number	Group Description	EPA Waste ID Code	Waste Description
1	Wood Preserving	K001	Bottom Sediment Sludge from the treatment of wastewater from wood preserving processes that use creosote and/or pentachlorophenol
2	Acrylonitrile	K011 K013 K014	Bottom stream from the wastewater stripper and columns used in the production of acrylonitrile
3	Halogenated Aliphatics	K016 K017 K018 K019 K020 K028 K030 K095 K096 K116 K119 K136 F024	Heavy ends and still bottoms of distillation residues from the production of chlorinated organic products
4	Non-chlorinated PNA (Polynuclear Aromatics)	K009 K010 K022 K023 K024 K087 K093 K094	Distillation bottoms and light ends from the production of organics

5	Organometallics	K031 K084 K101 K102	By-product salts, wastewater treatment sludges, tar residues, activated carbon residues, generated in the production of organics and pharmaceuticals.
6	Pesticides	K037	Wastewater treatment sludge from the production of disulfoton
7	Explosive Wastes	K045 K047	Spent carbon and pink/red water from the treatment of wastewater containing explosives
8	Refinery Wastes	K048 K049 K050 K051 K052	Dissolved air floatation (DAF) float, slop oil emulsions, cleaning sludge, separator sludge/ tank bottoms from the petroleum refining industry
9	High Metals-Containing Sludges/Dusts	K061	Emission Control Dust/sludge from the primary production of steel in electric furnaces

10	High Nitrogen Non-wastewaters	K025 K027 K083 K113 K114 K115	Distillation bottoms residues, vicinals and light ends from the production of nitrogen-containing organics
11	Chlorinated Aromatics	K015 K034 K043 K085	Still bottoms, filter solids, and distillation bottoms from the distillation of aromatic chlorinated organics
12	Solvent Washes	K086	Solvent washes and sludges from cleaning tubs and equipment used in the formulation of ink
13	High Nitrogen Wastewaters	K103 K104 K111 K112	Process residues and wastewater from aniline, dinitrotoluene and toluenediamine production of aniline
14	EP Toxic Pesticides	D012 D013 D014 D015 D016 D017	Endrin Lindane Methoxychlor Toxaphene 2,4-D (2,4-Dichlorophenoxy-acetic acid) 2,4,5-T Silvex

15	Spent Solvents	F001 F002 F003 F004 F005	Spent halogenated and nonhalogenated solvents
16	Dioxin-Containing Wastes	F020 F021 F022 F023 F024 F025	Wastes from the production or manufacturing use of chlorinated phenols or of intermediates used to produce their pesticide derivatives

The heating value of wastes varies from nearly zero for some wastes with very high moisture contents to around 15,000 Btu/lb (34,860 J/g) for plastic packaging materials.

Chlorine Content

Most chlorine in plastics or solvents in the waste feed react with hydrogen during incineration to form hydrochloric acid (HCl) which typically requires a downstream scrubbing system to remove it. This HCl is an emission which can create corrosion problems downstream from the incinerator itself, in the air pollution control train. Some fraction of the chlorine also goes to chlorinated PICs which wind up in the CBP emissions.

Ultimate Analysis

The ultimate analysis of a waste is an analysis of its basic elemental chemical composition such as its C, O, H, Cl, and S content. The ultimate analysis provides information relative to: (1) the quantity of combustion air needed during incineration; and (2) the quantity of ash to be produced after

incineration. Table 4 lists the ultimate analysis and heating value of a typical hazardous waste stream (7).

TABLE 4. TYPICAL ULTIMATE ANALYSIS OF HAZARDOUS WASTE

Carbon	36%
Hydrogen	9
Oxygen	3.8
Nitrogen	-
Sulfur	-
Chlorine	2.2
Moisture	4
Ash	45%
Heating Value: 9000 Btu/lb	

Moisture Content

Moisture is evaporated from the waste as the temperature of the waste is raised in the combustion chamber; it passes through the incinerator, unchanged, as water vapor. This evaporation of moisture uses energy and reduces the temperature in the combustion chamber. The water vapor also increases the combustion gas volumetric flow rate, which reduces combustion gas residence time.

MINIMIZATION OF THE IMPACT OF CBPs ON THE ENVIRONMENT

The following will address, in very general terms, some technology developments or pollution control measures which may have potential in minimizing the impact of CBPs on the environment. Many of the developments/controls discussed below would require additional research before they could be adopted on any wide scale. Nonetheless, if they were researched and found to be promising techniques of the future, their adoption/implementation/use at hazardous waste thermal destruction facilities would have the effect of minimizing the impact of CBPs on the environment.

For Unburned POHCs

Because the hazardous waste incinerators of today already average a Destruction and Removal Efficiency (DRE) of about 99.998% (1), it would appear that little can be done to minimize the emission of unburned POHCs. Requiring higher DREs would be an option (the current EPA standard is 99.99%), however, in this case, significant advancements in technology would be necessary before the higher DREs could be achieved. Presumably, operating at higher temperatures and for longer residence times would result in attaining higher DREs. [Some of the methods discussed below for the minimization/control of PICs may also work for the lessening of unburned POHCs in incinerator emissions.]

For PICs

Methods that have been proposed for PIC minimization or removal (8) include: (1) optimization of the combustion process itself to minimize the formation of PICs; (2) afterburning (this established practice should be quite useful in destroying many of the PICs that are formed in the primary combustion chamber); (3) enriched oxygen utilization; (4) catalytic oxidation of PICs (what is needed here is an extremely versatile, low-cost, poison-resistant, highly

effective catalyst); (5) scrubbing of the organic PICs using organic scrubbing media and efficient contactors; and (6) sorption of the organic PICs onto beds of activated carbon or other effective sorptive material. The first four of these technologies are, of course, high temperature methods, whereas the last two are (generally) low temperature processes.

For Metals

As discussed in the Introduction to this Paper, metals emissions at hazardous waste incinerators represent the most significant environmental risk (1). However, it is the opinion of the authors that this CBP can be minimized substantially by the use of highly efficient (though probably costly) air pollution control devices (APCDs). For example, if fixed or variable throat venturi scrubbers are to be used for both heavy metals and acid gas removal, build a high pressure drop (ΔP) into the design of this APCD --- on the order of 60 to 120 inches of water (1) --- for effective control of the metals-laden fine particulate.

For Residuals/Ashes

The minimization of this CBP is difficult in that it is tied heavily to the amount of ash in the incoming hazardous waste fed to the incinerator. The non-volatile fraction of the ash ends up (for the most part) in the incinerator bottom ash, whereas much of the volatile fraction ends up in the fly ash (most all of which is captured in the downstream APCD). Control of these ashes can be achieved by utilization of landfill lining/leachate collection (and treatment) systems or by solidification/stabilization processes. Residuals can include: (1) scrubber blowdown wastewaters; (2) lime-/limestone-laden fly ashes from APCDs; and (3) spent activated carbons that have been removed from APCD service. Control of these residuals is generally accomplished using conventional

technologies.

CONCLUSION

Except for incineration, no other state-of-the-art treatment technology can treat hazardous waste to the extent required by the RCRA incineration regulations (i.e., none can achieve even the 99.99% destruction and removal efficiency). Because incineration produces trace amounts of unwanted CBPs, it is very important to carry out thorough research and development programs to search for solutions to the issues that surround them. Widespread adoption of these technological solutions will make incineration the technology-of-choice for the hazardous waste disposal problems of the future.

REFERENCES

1. Oppelt, E.T., "Incineration of Hazardous Waste: A Critical Review," the Journal of the Air Pollution Control Association (JAPCA), 37, 5, 1987.
2. Lee, C.C., Environmental Engineering Dictionary, published by Government Institutes, Inc., 966 Hungerford Dr., #24, Rockville, MD 20850, September 1989.
3. "National Survey of Hazardous Waste Generators and Treatment, Storage and Disposal Facilities Regulated Under RCRA in 1981," EPA/530/SW-84/005, NTIS PB86-197337, April 1984.
4. "Fact Sheet on Waste Treatment Capacity," EPA's Office of Solid Waste and Emergency Response, November 1989.
5. Lee, C.C., Huffman, G.L. and Oberacker, D.A., "Hazardous/Toxic Waste Incineration," Journal of Air Pollution Control Association, Volume 36, No. 8, pp. 922-931, 1986.
6. Lee, C.C. and Seeker, W.R., "Comparison of the Incineration of Medical Waste with Hazardous and Municipal Waste," presented at the 82nd Annual AWMA (Air and Waste Management Association) Meeting & Exhibition Conference, Anaheim, CA, June 25-30, 1989.
7. "Guidance on Setting Permit Conditions and Reporting Trial Burn Results," EPA/625/6-89/019, January 1989.
8. Olexsey, R.A., Huffman, G.L. and Evans, G.M., "Emissions and Control of By-Products from Hazardous Waste Combustion Processes," in the Proceedings from EPA's 11th Annual Research Symposium, EPA/600/9-85/028, September 1985.